Geomechanical Characterisation of Reservoir and Seal Rocks in the Taranaki Basin:

Defining empirical relationships between rock property parameters

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1. Introduction

Around the world, extensive work has been undertaken to understand the geomechanical properties of sands and shales, for application to the modelling of petroleum reservoirs. Geomechanics provides vital information on the *in-situ* stresses within a basin, and how they impact the flow of fluids through reservoirs. This study focuses on the Maui and Maari Fields in the Southern Taranaki Basin, which contain substantial petroleum reserves for New Zealand, and presents the data attributed to analogue samples from the Palaeocene reservoir, the Farewell Formation.

Despite development and interest in the resources hosted here, an absence of geomechanical data for the region means industry relies on non-site specific geomechanical properties, for stress field calculations required for well stability, and calculations of vital data such as permeability from wireline logging. This has downstream implications for any decisions that need to be made on well design and field planning.

We aim to quantify the geomechanical properties of key reservoir and seal horizons in the Maari and Maui Fields, including porosity, permeability and ultrasonic wave velocities (V_p/V_s) and UCS, consider the effect of anisotropy on these properties, and following a practical approach, determine empirical relations, to allow for correlation between laboratory and wireline data.

2. Methods

Laboratory testing was undertaken on dry core samples of the outcropping Farewell Formation to generate it's geomechanical rock properties. Three variations of sandstone were selected from different locations (Fig.1).

Ultrasonic velocities measurements are recorded across structurally orientated samples (Fig.2), to illustrate the influence of anisotropy on the mechanical rock properties. Used in conjunction with pycnometer porosity readings, we can define the observational correlation between Vp/Vs and porosity.

Optical microscopy allows a in-depth look at the fine-scale geological controls resulting in variation of data trends across lithologies.

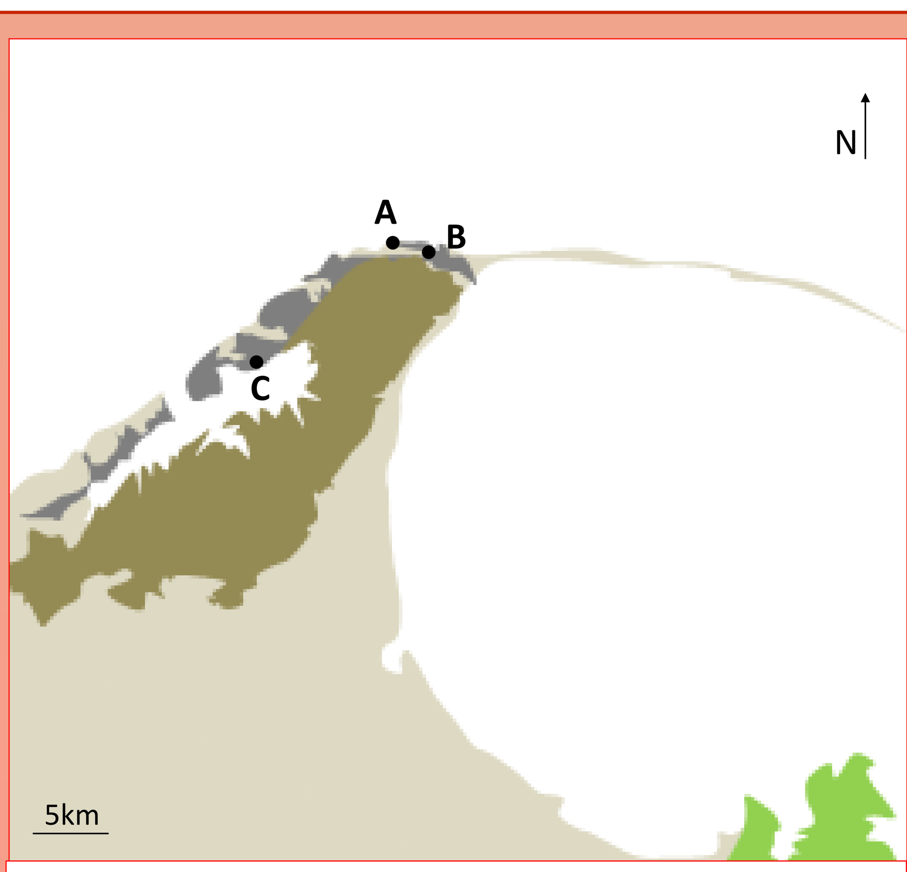


Fig.1 The Farewell Formation, a fluvial-deltaic environment, outcrops at the north-western point of the South Island. Samples were acquired at three localities; Wharariki Beach (A), Pillar Point (B)and Oyster Point (C)

3. Using Ultrasonic Wave Velocities

The primary (Vp) and shear wave (Vs) velocities, of a specific rock, provide data for calculating mechanical rock property parameters, including the Young's Modulus, Poisson's Ratio, and Vp/Vs Ratio.

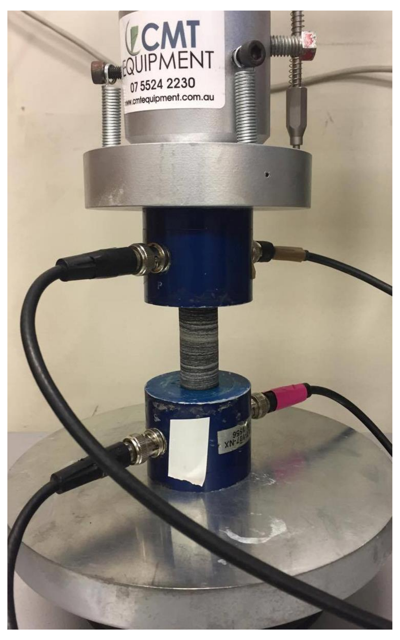


Fig. 2 Ultrasonic Velocity Measurement System under a low uniaxial load.

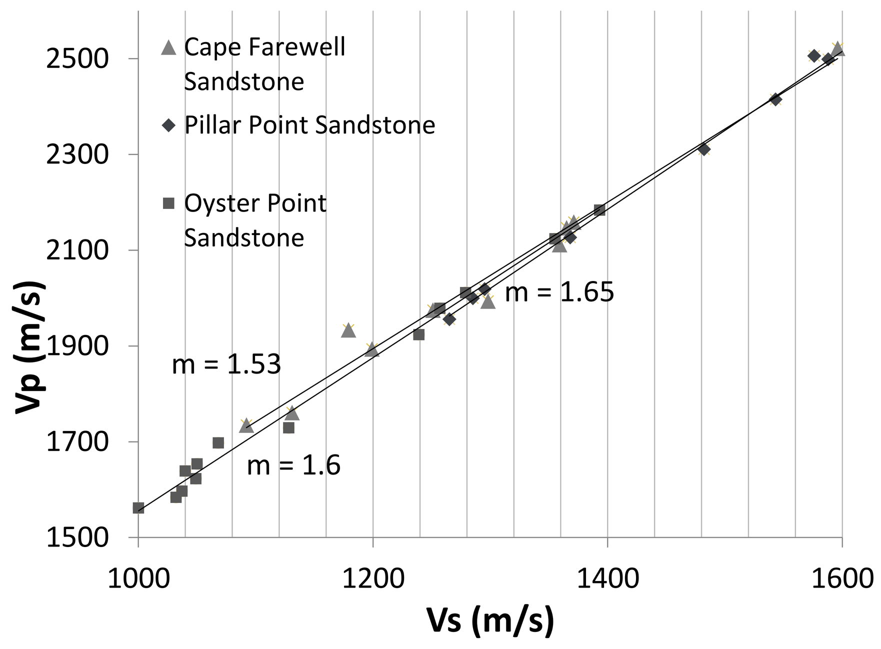
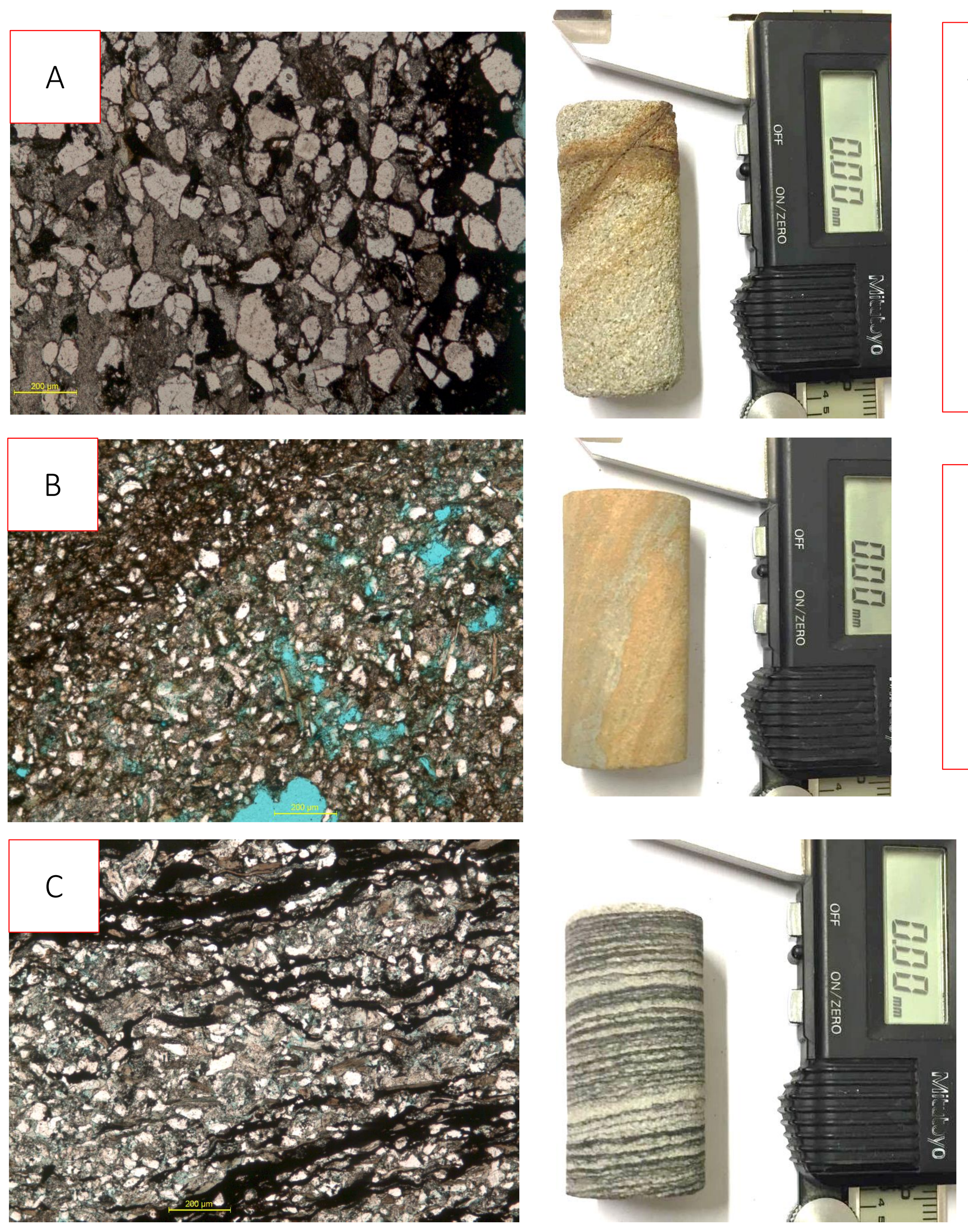


Fig. 3 The Vp/Vs ratios, acquired from the trendline gradients, depict a strong correlation with values falling between 1.52 and 1.6, indicative of a sandstone type lithologies.

4. Influence of Anisotropy on Elastic Properties



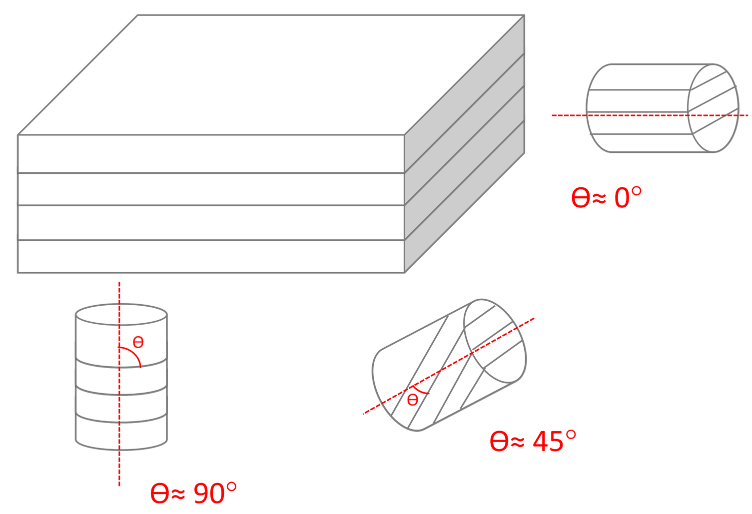
A. Wharariki Beach
Fractured, soft, fine to medium grained, beige sandstone with sets of cross cutting bands.

B. Pillar Point
Hard, very fine to fine grained, orange, clayey, laminated sandstone.

C. Oyster Point
Soft, Very fine grained, grey, laminated, organic rich, sandstone.

Fig. 3 illustrates the intrinsic anisotropy observed in the lithologies from locations A, B and C. The optical images and core samples demonstrate the anisotropic nature on both a microscale and macroscale.

Fig. 4 demonstrates the azimuth angle. Vp is faster parallel to layering as this provides streamlined wave propagation, Vs is dependent on the azimuth, as polarised wave encounters structures in all orientations.



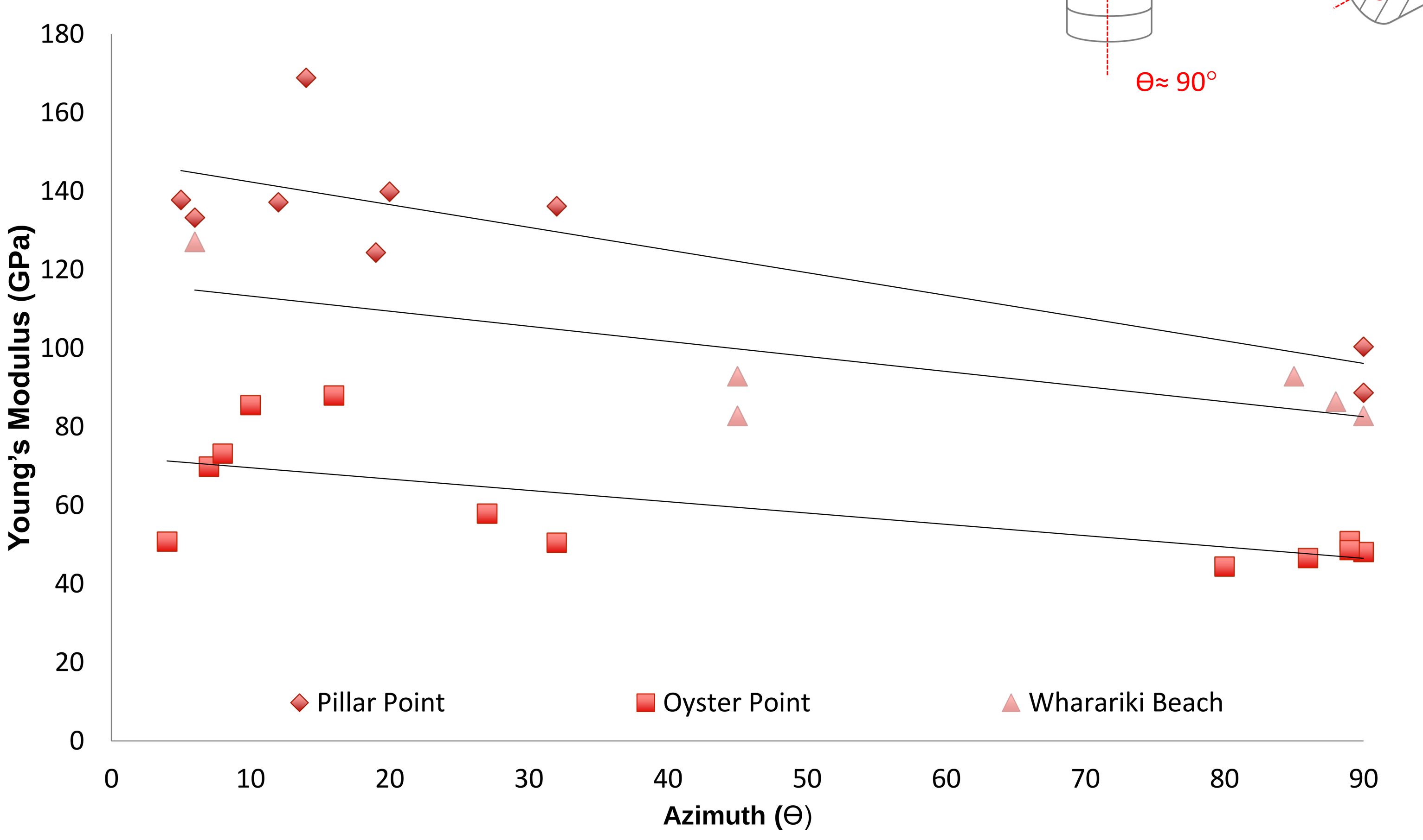


Fig. 5 displays the negative correlation between the Young's Modulus and Azimuth, in all three lithologies, suggesting the Youngs Modulus is stronger parallel to the anisotropic layer. The Young's Modulus, a measure of the elasticity in the sample, can be directly calculated from the wave velocities.

4. Optical Microscopy

Dependent on the inhomogeneous nature of the rock, porosity can vary with orientation, as seen at Pillar Point.

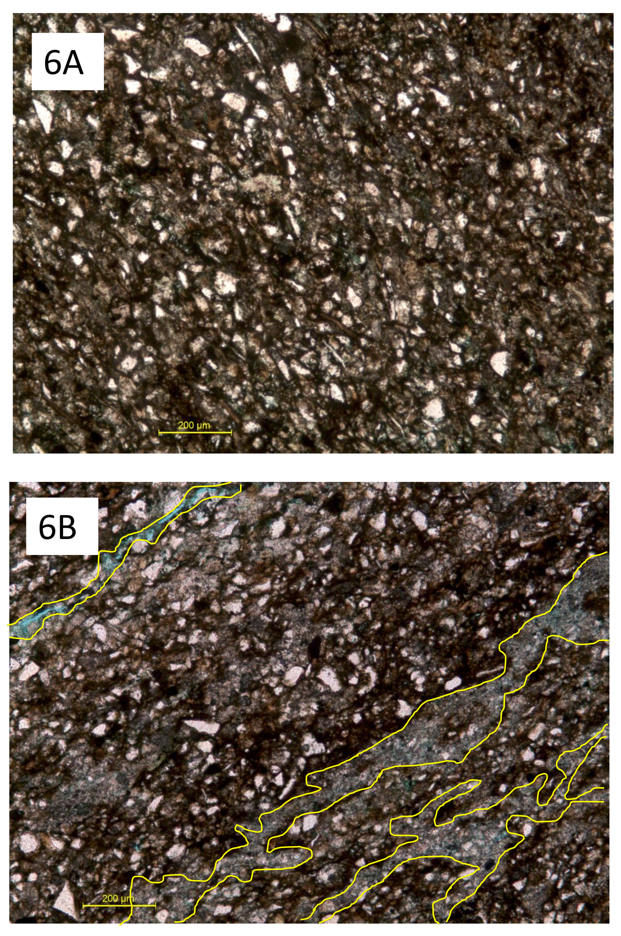


Fig. 6A Parallel to laminations display little porosity or permeability potential.

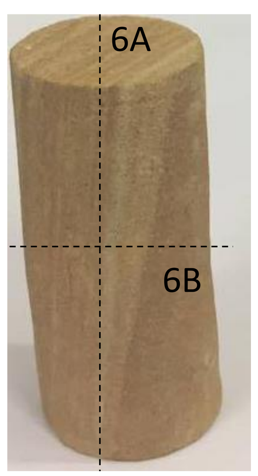
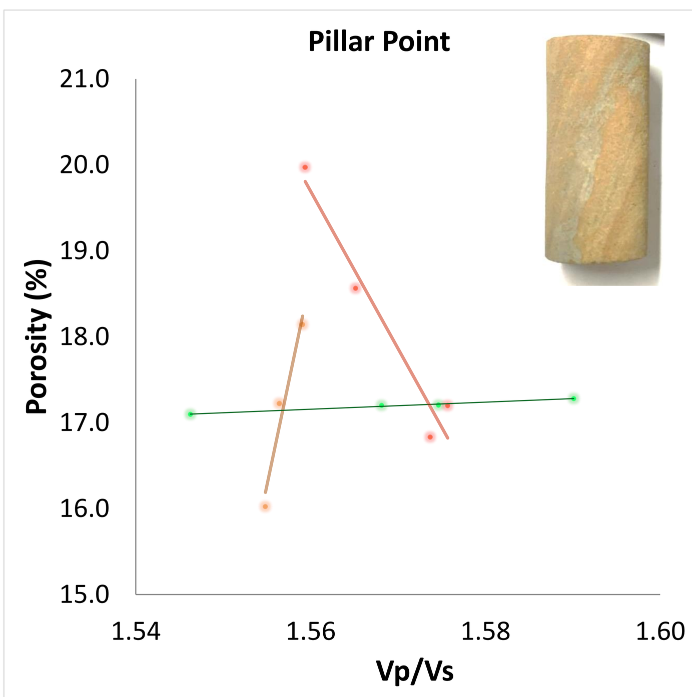
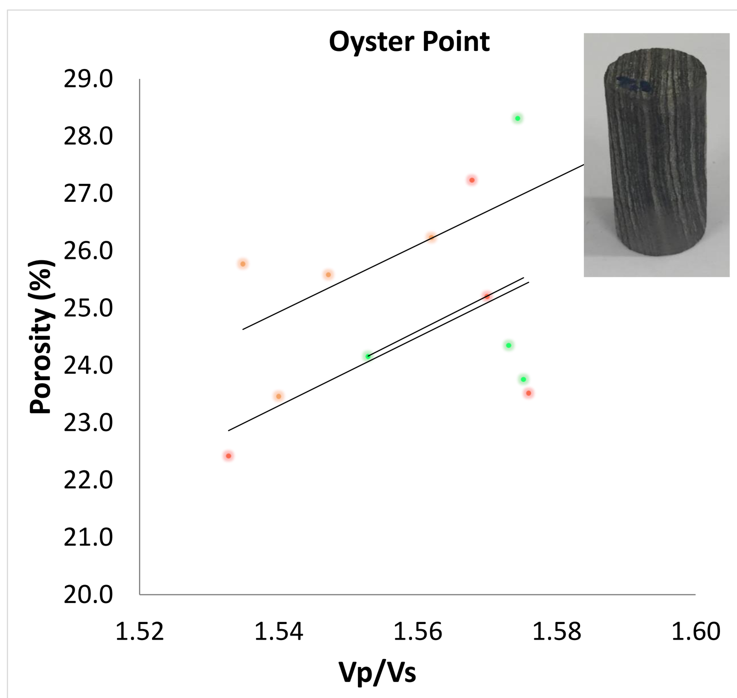


Fig 6B. Perpendicular to laminations. Obvious bands present and increased porosity.

6. Defining Empirical Relations between Vp/Vs and Porosity

In figure 5A (Left), Pillar Point demonstrates a varied Vp/Vs to porosity relationship between parallel, oblique and perpendicular orientations. Thus in order to define a relationship between the two parameters, porosity and Vp/Vs ratio, each orientation should be treated separately.





In figure 5B (Right), Oyster Point displayed scattered data, with no specific trends. This can be attributed to the sporadic nature of the organic matter in the samples, although appearing well laminated at first glance. This is supported by the high porosity values, observed in all samples , regardless of orientation.

7. Summary

- Vp/Vs can be used as a lithology indicator on a broad scale, but intrinsic rock detail is required to interpret the wave velocities.
- Empirical relations between the rock properties, specific to the region, allow for correlation between laboratory, wireline, and field wide geophysics scales.
- The anisotropic nature of a rock can influence both the elastic properties and porosity.
- When defining empirical relationships between rock parameters, they must be adapted based on orientation, if anisotropy is present, on both a micro and macroscale..

7. References

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Palchik, V., 1999, Influence of Porosity and Elastic Modulus on Uniaxial Compressive Strength in Soft Brittle Porous Sandstones: Rock Mechanics and Rock Engineering, v. 32, no. 4, p. 303-309